A WATER VAPOUR BARRIER AND A METHOD OF MAKING THE SAME

The present invention relates to a water vapour barrier of the type used in building structures such as roof or wall structures. It is well known to use such vapour barriers in the form of plastic films or other sheet materials between a roof or wall structure and a ceiling or wall covering of a room in a building. Usually, the roof or wall structure defines cavities therein which are totally or partly filled with a heat insulating material. Due to for example leakage and/or water vapour condensation caused by variation in temperature moisture may accumulate in the cavities of the roof or wall structure, and such moisture may cause corrosion of structural elements of metal and fungus or rot attack on structural elements of wood.

The international patent application No. WO 96/33321 discloses a water vapour barrier for use in heat insulation of buildings. This known vapour barrier is in the form of a plastic film or a membrane of the type having a water vapour diffusion resistance, which varies in dependency of the relative moisture of surrounding air. This means that when the relative moisture within the roof or wall structure is high, the diffusion resistance of the vapour barrier will be low - typically a diffusion resistance equivalent to 0.2 m air column (according to DIN 52 615) - so that moisture from the cavities of the roof or wall structure may diffuse through the vapour barrier and into the room of the building. However, when the relative moisture on the warm side of the roof or wall structure is low, for example in the winter, the diffusion resistance of the vapour barrier will be higher, typically equivalent to 2 m air column - but a substantial amount of water vapour may diffuse from the room of the building into the roof or wall structure, which is undesirable. Furthermore, this known vapour barrier is water tight, which means that free water which may have leaked into cavities of the roof or wall structure is collected therein and can only very slowly diffuse or condense in the summer through the vapour barrier after having been vaporised.

The European patent No. EP 0148870 discloses a vapour barrier formed by a pair of vapour impervious plastic films made from polyethylene, and an intermediate water absorbing layer. The oppositely arranged vapour impervious plastic films have through openings defined therein. However, the openings in the opposite plastic films are offset or displaced in relation to each other. This known vapour barrier structure allows vapour to dry out through the barrier via condensation and by capillary action and the vapour diffusion resistance is dependent on the character of the intermediate layer of water

absorbing material and on the minimum spacings of adjacent op nings in the opposite vapour impervious plastic films. This known water vapour barrier also allows free wat r accumulated within cavities of a roof or wall structure to be drained through the vapour barrier by capillary action. However, when this known laminated water vapour barrier is used, vaporised moisture may dry out from the roof or wall structure through the vapour barrier via condensation and capillary action into an inner room of the building only when the relative humidity and the temperature difference between the roof or wall structure and the vapour barrier is such that vapour is condensed on the intermediate layer of water absorbing material which is exposed at the openings defined in the outer plastic film. This means that the roof or wall structure may dry out only when there is a sufficiently fall of temperature in the roof or wall structure, such that the temperature outside is higher than the temperature in the room or inner space of the building.

The present invention provides an improved vapour barrier of the latter type. Thus, the present invention provides a water vapour barrier comprising a first, water impervious membrane having a plurality of first through openings defined therein, a second, water impervious membrane arranged opposite to the first membrane, and water absorbing material being arranged within one or more spaces being defined between the first and second membranes, and the vapour barrier according to the invention is characterised in that at least part of said second membrane is of a material of the type having a water vapour diffusion resistance, which varies in dependency of the relative humidity of air in contact therewith, such that the vapour diffusion resistance is reduced when the relative humidity increases, and vice versa.

The second membrane may have a plurality of second through openings defined therein, and the first through openings in the first membrane may be offset in relation to the second through openings in the second membrane, or the first and second openings may be placed opposite to each other.

Preferably, the water vapour barrier may be arranged such that the first membrane, which is impervious to water, is facing the room of the building while the second membrane through which water vapour may diffuse is facing outwardly towards the building structure. By means of the vapour barrier according to the invention moisture may be remov d from a roof or wall structure or another similar building structur not only by draining of free water and by removing condensed water vapour by capillary action like the known vapour

barrier, but also by diffusion. This means that the vapour barrier according to the invention is much more efficient in drying cavities or spaces in building structures, which may partly or totally be filled with insulating material, than any of the known vapour barriers.

Alternatively, the water vapour barrier according to the invention may be reversed arranged such that the first membrane, which is impervious to water, is facing outwardly towards the building structure, while the second membrane through which water vapour may diffuse is facing the room of the building.

Like the second water impervious membrane also the first membrane may be of the type having a water vapour diffusion resistance varying in dependency of the relative humidity of the ambient atmosphere. In the presently preferred embodiment of the water vapour barrier according to the invention, however, the first membrane is substantially impervious not only to water, but also to water vapour.

The water absorbing material may, for example, be arranged within a plurality of pockets or spaces which are formed between the first and second membrane, and each of which interconnects one or more of said first openings in the first membrane with one or more of said second openings formed in the second membrane. Preferably, however, the first and second membranes are connected to opposite sides of said water absorbing material, which is in the form of an intermediate layer, and the first through openings in the first membrane are offset in relation to the second through openings in the second membrane.

The characteristics of the water absorbing material forming the intermediate layer, the minimum spacing between adjacent first and second openings in the opposite first and second membranes, and the thickness of the intermediate layer may be chosen so as to obtain a desired draining effect and a desired resistance against moisture transmission from the first to the second openings by capillary action. It has been found that the thickness of the intermediate layer of water absorbing material should preferably be 0.2-1.5 mm.

In a preferred embodiment, the second openings cover a substantially larger area of the surface of the water absorbing material than the first openings, so that the vapour barrier is more open from the side wh re the second membrane is fastened, and thereby provides that the vapour or water is easier transported in a dir ction from the second

membrane to the first membrane, due to the lower diffusion resistance of one side of the vapour barrier, and ther by a more rectified transport of the vapour or water in the vapour barrier is obtained. Alternatively, the first through openings may cover a substantially larger area of the surface of the water absorbing material than the second through openings, so that the vapour barrier is more open from the side where the first membrane is fastened.

The intermediate layer may be formed by any suitably water absorbing material, such as a porous, moisture resistant material. Preferably, however, the intermediate layer is a fibrous material and may comprise modified natural or man-made fibres, such as modified cellulose fibres or plastic fibres which may, for example, be impregnated with a fungicide. In the preferred embodiment the intermediate layer is formed by a mixture of plastic fibres, such as polypropylene and acrylic fibres. The fibres may have a core, which is hydrophobic, and an outer surface which is hydrophilic. Preferably, the weight of the intermediate layer is 50-100 g/m^2.

The first membrane is, of course, not totally impervious to water vapour, but should preferably show a vapour diffusion resistance being equivalent to at least 10 m air column at any moisture conditions. Usually, the water vapour diffusion resistance of the first membrane, which is said to be substantially impervious to water vapour, should be equivalent to 10-100 m air column at any relative humidity of air in contact therewith, but the water vapour diffusion resistance may also be equivalent to 2000 m air column or even higher depending on the chosen material, e.g., metal foils. The first membrane could be formed in situ, for example by spraying the membrane in a liquid condition on one side surface of the intermediate layer of water absorbing material. Preferably, however, the first membrane is a film or foil made from a plastic or a metallic material, such as polyethylene, polypropylene, poly-vinyliden-chloride, coated films of metals, such as aluminium laminates, aluminium or an alloy thereof. In the presently preferred embodiment the first membrane comprises a polyethylene film having a weight of 20-100 g/m^2, preferably 30-80 g/m^2. Preferably, the thickness of the first membrane is 10-200 μm, such as 40-100 μm.

The water vapour diffusion resistance of the second membrane is preferably equivalent to at least 2 m air column at a relative humidity of 20-50% and less than 1 m air column at a relativ humidity of 60-100% of air in contact with the membrane. This means that when

the water absorbing material is moist or the air within the water absorbing material has a high r lative humidity the r sistance against moisture diffusion from the water absorbing material through the second membrane and into the inner space or room of the building is low. Consequently, moisture may be removed from the cavities or spaces in the roof or wall structure relatively quickly. However, in winter time when the relative humidity on the side of the vapour barrier facing outwardly is lower than the relative humidity of the air inside the building, the resistance against diffusion of water vapour from the inner space or room of the building into the roof or wall structure is relatively high.

In a preferred embodiment, the water vapour diffusion resistance of the second membrane is even higher and may be equivalent to at least 5 m air column or even higher, such as up to 60 m air column, at a relative humidity of 20-50%. Furthermore, the water vapour diffusion resistance of the second membrane may be equivalent to less than 0.5 m air column, and preferably about 0.1 m or less at a relative humidity of 60-100% of air in contact with the membrane, whereby the moisture transmission capacity of the vapour barrier is increased substantially. Preferably, the thickness of the second membrane is 10-100 μm, such as 10-60 μm.

The water vapour diffusion resistance of the vapour barrier may be equivalent to at least 0.2 m air column at a relative humidity of 60-100% or even higher, such as up to 100 m air column at a relative humidity of 20-50%. When the relative humidity is at the most 99%, the vapour barrier dries out moisture by diffusion, and when the relative humidity is 100%, the vapour barrier removes condensed water vapour by capillary action and free water by draining the free water, as the vapour diffusion resistance drops to approximately 0.05 m air column when the relative humidity reaches 100%, e.g., in the summer period. This means that the vapour barrier according to the invention is much more efficient in drying cavities or spaces in building structures than known vapour barriers, as it is able to dry both by diffusion, condensation and drainage.

Oppositely, in the winter period when the relative humidity is 20-50%, the vapour diffusion resistance of the vapour barrier may be up to 100 m air column, and the vapour barrier may then substantially prevent vapour from diffusing from the room through the barrier and into the roof or wall structure, and it thereby prevents a moisture accumulation in the structure.

At least part of the second membrane may be made from any of the known materials having a water vapour diffusion resistance which is dependent on the relative humidity of air in contact therewith, for example the materials disclosed in the above mentioned international application WO96/33321. As example the second membrane may comprise any of the following materials or any combinations thereof, namely polyamide, ethylene-vinyl alcohol-copolymer, polyvinyl alcohol, polyurethane, protein derivatives, methyl-cellulose, linseed oil alkyd, cellophane, and bone glue. Some of these materials are suitably made in the form of a film which is adhered to or laminated with the intermediate layer of water absorbing material. Other of the materials mentioned may be formed into the second membrane by being applied to, for example sprayed onto a side surface of the intermediate layer of water absorbing material in a liquid condition. Preferably, the at least part of the second membrane constitute approximately 5-20% of the entire surface area of the vapour barrier, so as to obtain a preferred water vapour diffusion resistance of the vapour barrier.

An adhesive for adhering the first and/or second membrane to the layer of water absorbing material may be provided on the membrane(s) by coextruding the membrane(s) with the adhesive when producing the membrane(s). The adhesive may have perforations for retaining the permeability of the water vapour barrier in the adhering areas.

A preferred embodiment of the vapour barrier according to the invention further comprises a moisture distributing outer layer of water absorbing material which may be connected to the outer surface of the first and/or second membrane. Such moisture distributing layer may efficiently absorb and distribute free leakage water or condensed vapour and transfer such water to the water absorbing material, which is positioned between the first and second membranes and exposed at the openings formed in the first membrane. This outer layer of water absorbing material may be of any suitable type, for example of the same type as that used in the water absorbing intermediate layer. Thus, the outer layer of water absorbing material may be a fibrous, felt-like material, which may, for example, contain a mixture of plastic fibres. The thickness of this outer layer is preferably rather small, for example less than 0.5 mm and preferably about 0.1 mm. Preferably, the weight of the outer layer is 10-20 g/m^2.

The first and/or second membrane may be formed as a continuous layer extending along the entir length of the vapour barrier. Thus, the vapour barrier may comprise first and/or

second membrane(s) being formed as continuous layers, so as to obtain a vapour barrier having a higher diffusion resistance. The first and/or second membranes may be continuous films or foils in which a plurality of openings, which may have any suitable contour, such as circular, elliptical, triangular or rectangular, are formed. Furthermore, the total area of the openings in the first and second membranes may be different, thus, as an example the total area of the openings in the second membrane may exceed the area of the openings in the first membrane.

The openings in the first and/or second membrane may comprise perforations with a closeness being between 200-600 holes per dm^2. Preferably, the perforations constitute 1-20% of the entire area of the membrane, such as 2-15%. The perforations may be placed in preferred patterns or randomly in the membrane. In case the perforations comprise circular holes, the diameter of the holes may be between 0.5-10 mm, and the perforations may be punched or rolled in the membrane, e.g., by flame-rolling the holes. The perforations in the first membrane may be offset in relation to the perforations in the second membrane, or the perforations in the first membrane may be positioned opposite to the perforations in the second membrane.

In the preferred embodiment the first and second membranes are formed by mutual parallel, transversely spaced first and second bands or strips, respectively, and the first and second openings in the first and second membranes, respectively, are then defined between adjacent first and second bands, respectively. As mentioned above, the first and second openings do not mutually overlap, but should be offset. Preferably, the minimum spacing between first and second openings, which are defined in the first and second membranes, respectively, is about 20 mm in order to obtain a sufficient resistance against the capillary transmission of water from a first opening in the first membrane to and adjacent second opening in the second membrane. Furthermore, the first and second bands may be perforated with perforations as described above.

When the first and second membranes are formed by first and second bands, respectively, each of the second bands may have a width exceeding the width of a corresponding strip-like space between adjacent first bands, so that such second band overlaps not only such space in the first membrane, but also adjacent rim portions of said adjacent first bands. In such case the maximum transverse overlap of th rim portions of

th adjacent first band may be 100 mm. However, pr ferably such maximum transverse overlap is 70 mm.

In the preferred embodiment the vapour barrier according to the invention is in the form of a web-like material with the parallel, band-shaped or strip-like openings extending in the longitudinal direction of the web-like material.

In a further embodiment, the vapour barrier may comprise a combination of a first membrane being formed by first bands and a second membrane being formed as a continuous layer extending along the entire length of the vapour barrier, or vice versa. The bands and the continuous layer may be perforated, and the perforations in the bands may be offset and/or positioned opposite in relation to the perforations in the continuous layer.

Preferably, the vapour barrier has a heating value being at the most 4 MJ/m^2, so that it complies with the regulations concerning fire resistance.

One or more of the layers of the vapour barrier may comprise polyamid/nylon, so as to provide a vapour barrier having improved fire-retardant properties. When being burned nylon produces nitrogen which has a fire extinguishing effect.

Furthermore, it has been found that the vapour barrier according to the present invention has improved sound absorption properties.

The invention also provides a method of making a water vapour barrier of the type described above, said method comprising forming an elongated layer of water absorbing fibrous material, applying to a first side surface of the layer of water absorbing material a plurality of transversely spaced, parallel first bands of a first, water impervious membrane material, and applying to an opposite, second side surface of the layer of water absorbing fibrous material a plurality of transversely spaced, parallel second bands, at least some of which are of a second, water impervious membrane material, which is of the type having a water vapour diffusion resistance, which varies in dependency of the relative moisture of air in contact therewith, each of said second bands having a width exceeding the width of a corresponding space between adjacent first bands and b ing applied so as to ov rlap said space and adjacent rim portions of said adjacent first bands.

At least some of the first and second bands may be films or foils which are adh red to the side surfaces of the layer of water absorbing fibrous material. The first bands, may, for example, be polyethylene films or foils which are connected to thermoplastic fibrous of the layer of water absorbing material by heating or fusing. Preferably, at least some of the second bands are fastened to the layer of water absorbing material by means of a glue, being applied at spaced locations. This may be done by interposing net-like bands of a suitable polymer glue between said second bands and the layer of water absorbing material and by subsequently activating the glue, for example by heating.

The invention will now be further described with reference to the drawings, wherein

Fig. 1 is a fractional sectional view of a roof structure including a water vapour barrier according to the invention,

Fig. 2 is a diagrammatic sectional view of an embodiment of the water vapour barrier according to the invention shown in an enlarged scale,

Fig. 3 is a perspective view of a rolled up web-like water vapour barrier according to the invention, and

Figs. 4-8 are diagrammatic sectional views of further embodiments of the water vapour barrier according to the invention shown in enlarged scales.

The roof structure shown in Fig. 1 comprises a wooden frame including rafters 10 (only one shown in Fig. 1) and a layer of boards 11, which are fastened to the upper sides of the rafters 10. The spaces defined between the rafters 10 and by the layer of boards 11 are filled with a heat insulating material, such as mineral wool 12. The layer of boards 11 is covered by an outer layer of roofing felt 13 and by a water tight film or foil 14 arranged between the roofing felt and the boards 11. The inner side of the heat insulating material or mineral wool 12 is covered by a water vapour barrier 15 according to the invention, and the inner side of the vapour barrier is covered by lining plates, such as plasterboards 16 which are fastened to laths 17. The purpose of the water vapour barrier 15 shown in Fig. 1 is to allow possible moisture collected within the spaces defined between the rafters 10 to migrate through the vapour barrier 15 and into the room below th plast rboards 16. The moisture may, for example, be free water having passed through possible leaks in the

roofing felt 13 and/or the film 14, or it may be condensed water vapour or air with a high relative humidity.

In the winter, the vapour diffusion resistance of the vapour barrier 15 may be up to 100 m air column, and the vapour barrier may then substantially prevent the moisture from diffusing from the room through the vapour barrier and into the roof structure, and it thereby prevents a moisture accumulation in the roof structure.

Figs. 2-8 show further embodiments of the water vapour barrier, and wherein like parts do have the same reference number.

Fig. 2 diagrammatically illustrates an embodiment 15 of the water vapour barrier according to the invention more in detail. The water vapour barrier 15 shown in Fig. 2 comprises an intermediate thin layer 18 of a water absorbent material, such as a fibrous material which may be a mixture of polypropylene fibres and acrylic fibres. The thickness of the layer 18 may, for example, be 0.5-1 mm. A first membrane 19 of a polyethylene film is fastened to the upper surface of the intermediate fibrous layer 18. The first membrane 19 is formed by a number of mutually parallel bands 20 of a polyethylene film. The bands or strips 20 are mutually transversely spaced so as to form band-like or strip-like openings 21 therebetween. A second membrane 22 is applied to the lower surface of the intermediate layer 18, for example by means of a polymer glue. The second membrane 22 is also formed by a number of parallel bands or strips 23 of plastic film. Each of these bands or strips is positioned opposite to one of the openings 21, so as to overlap not only this opening, but also adjacent rim portions of the bands 20. At least some of the bands or strips 23 are made from a plastic material of the type having a water vapour diffusion resistance which is dependent on the relative humidity of the air being in contact therewith. Thus, at least some of the strips 23 may be made from polyamide. Also the strips or bands 23 are mutually transversely spaced so as to define band-like or strip-like openings 24 therebetween, and as shown in Figs. 2 and 3 these openings are transversely offset in relation to the openings 21 formed in the first membrane 19. The opposite surface of the first membrane 19 is covered by a fibrous, water absorbing layer 25, which is preferably rather thin, for example 0.1 mm.

As explained above, moisture may pass from the spaces of the roof structure through the water vapour barrier and into an inn r room of the building in various ways. Free wat r

which comes into contact with the outer water absorbing layer 25 will be distributed along the upper surface of the first membran 19 and passed to the op nings 21 in the first membrane where the water may come into contact with and be absorbed by the intermediate layer 18. Now, as indicated by an arrow 26 the water may be passed to the opening 24 in the second membrane 22 by draining or capillary effect. Furthermore, as long as the relative humidity of air within the roof structure and consequently at the openings 21 in the first membrane 19 is higher than in the room defined by the plasterboards 16, water vapour also diffuses through the second membrane 22 as indicated by an arrow 27 in Fig. 2. However, in case the relative humidity of air within the roof structure drops below the relative humidity of air in the inner space of the building, the vapour diffusion resistance of the second membrane will increase so that only negligible amounts of humidity may pass into the spaces defined by the roof structure.

Fig. 4 diagrammatically illustrates a further embodiment 15 of the water vapour barrier according to the invention. The water vapour barrier 15 of Fig. 4 differs from that of Fig. 2 in that the first membrane 19 is fastened to the lower surface of the intermediate layer 18 and the second membrane 22 is fastened to the upper surface of the intermediate layer 18, and in that the first membrane 19 is formed as a continuous layer extending along the entire length of the vapour barrier. The first membrane 19 comprises perforations 28 being positioned opposite to the strips 23 of the second membrane 22.

Fig. 5 diagrammatically illustrates a further embodiment 15 of the water vapour barrier. The water vapour barrier 15 of Fig. 5 differs from that of Fig. 2 in that the first membrane 19 is fastened to the lower surface of the intermediate layer 18 and the second membrane 22 is fastened to the upper surface of the intermediate layer, and in that the first membrane 19 is formed by a number of parallel bands or strips 20. The bands or strips 20 are mutually transversely spaced so as to form band-like or strip-like openings 21 therebetween, the openings 21 being offset in relation to the openings 24.

Fig. 6 diagrammatically illustrates a further embodiment 15 of the water vapour barrier. This embodiment differs from that of Fig. 2 in that the second membrane 22 is formed as a continuous layer extending along the entire length of the vapour barrier. The second membrane 22 comprises p rforations 29 being positioned opposite to the strips 20 of the first membrane 19.

Fig. 7 diagrammatically illustrates a further mbodiment 15 of the water vapour barrier. The water vapour barri r 15 of Fig. 7 differs from that of Fig. 2 in that the first membrane 19 is fastened to the lower surface of the intermediate layer 18 and the second membrane 22 is fastened to the upper surface of the intermediate layer 18, and in that the first and second membrane 19,22 are formed as continuous layers extending along the entire length of the vapour barrier. The first membrane 19 comprises perforations 28 which are positioned opposite to the perforations 29 of the second membrane 22.

Fig. 8 diagrammatically illustrates a preferred embodiment 15 of the water vapour barrier. The water vapour barrier 15 of Fig. 8 differs from that of Fig. 4 in that the water absorbing layer 25 of Fig. 4 is removed, and in that the second membrane 22 constitutes a smaller part of the upper surface area of the vapour barrier, so as to thereby obtain a more vapour open barrier. The first membrane 19 comprises perforations 28 being positioned opposite to the strips 23 of the second membrane. The more openness of the barrier provides that the transport of vapour in a direction from the second membrane 22 to the first membrane 19 is predominant, and thereby a more rectified transport of the vapour or water in the vapour barrier is obtained.

It should be understood that the water vapour barrier according to the invention may also be used in connection with other parts of buildings, such as wall or roof structures. Because the water vapour barrier according to the invention allows moisture to pass from the outer to the inner side not only by capillary action, but also by diffusion, the vapour barrier according to the invention is much more efficient than similar known water vapour barriers.